Application of Laser-Based Ultrasound to Glovebox Enclosed Materials

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We have investigated laser-based ultrasound applied to materials enclosed in gloveboxes or other types of enclosures. Applications include materials at elevated temperatures in furnaces, radioactive materials in gloveboxes and materials being joined in welding enclosures. Laser-based ultrasound is ideal for these remote applications because the technique does not require contact with the surface, and the laser beams can be transmitted through windows.

Project Goals

The main goal for this project is to perform initial studies to determine if laser-based ultrasound could be applied to materials important to LLNL, inside an enclosed laser welding station. Two main questions are to be answered by this project: 1) how well does ultrasound propagate in materials that are currently being welded by a laser welding process; and 2) will glovebox windows significantly affect the signal-to-noise ratio of the ultrasound generated and detected using laser-based systems?

Relevance to LLNL Mission

Joining technologies such as welding remain critical to manufacturing critical components at LLNL, which has state-of-the-art laser welding facilities. Nondestructive evaluation of the welds using a technique such as laser-based ultrasound can ensure that the welds meet the requirements. Provided that laser-based ultrasound can be used through the windows of a laser welding station, the potential exists for process control whereby the ultrasonic signal can determine when the appropriate welding depth has been reached.

FY2007 Accomplishments and Results

Contact ultrasonic tests (UT) were performed on vanadium (Va) and titanium (Ti) plates. These plates were the same alloys and the same thicknesses currently being welded in the LLNL

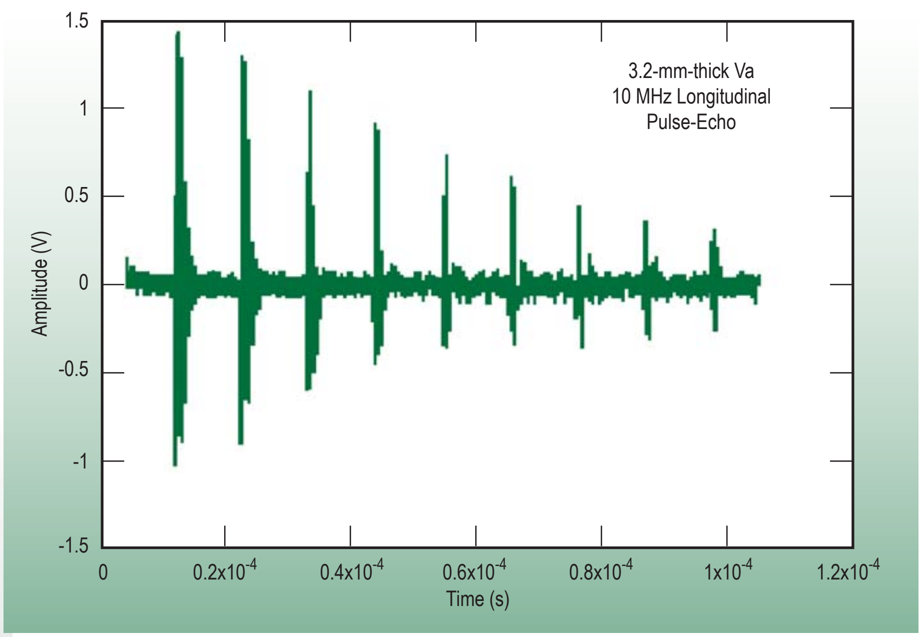

Figure 1. Amplitude vs. time trace in Va using a contact UT.

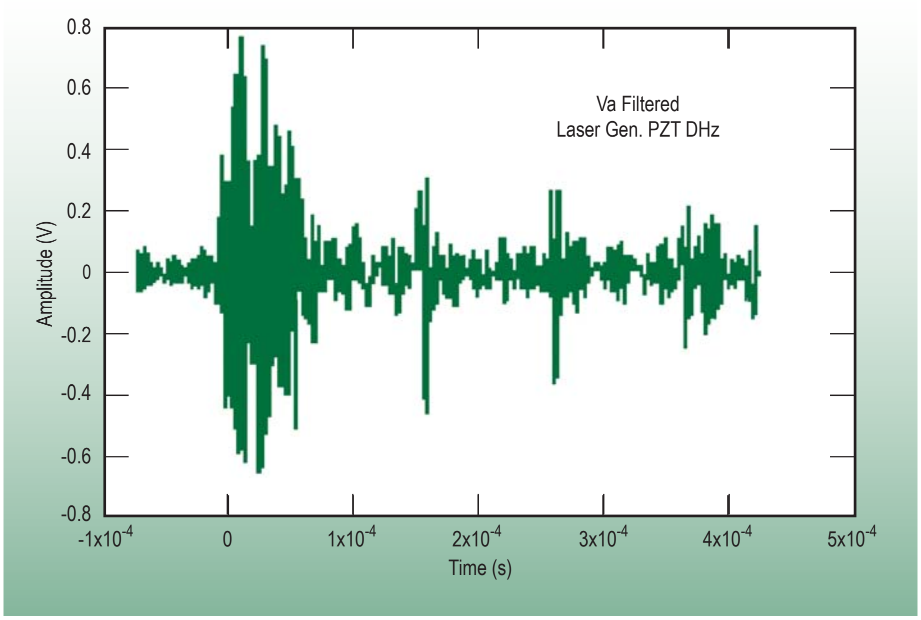

Figure 2. Laser generated ultrasound and contact detected in VA through a glovebox-like window.

laser welding stations. The piezoelectric transducers chosen for these tests had center frequencies of 10 MHz. For both of the materials, 10 MHz has a wavelength of approximately 0.6 mm, and should be sufficient to see voids or cracks on the order of 0.3 mm. The 10-MHz ultrasound propagated very well through the plates with very little attenuation, demonstrating that fairly high frequency ultrasound could be used for characterization of parts made from the Va and Ti alloys.

Figure 1 shows a typical amplitude vs. time ultrasound trace for the Va sample. Next, a through transmission test was set-up, whereby a pulsed laser was used to generate ultrasound in the plates, and a piezoelectric transducer was used to detect the ultrasound. This setup allowed a silica window, similar to those used in the welding station, to be placed in front of the sample on the side being hit by the pulsed laser to look for a reduction in signal-to-noise over the case when no window was present. The drop-off in signal level was negligible.

Figure 2 shows a laser generated signal obtained in Va. At this point, it was clear that laser-based ultrasound could indeed be applied to the Va and Ti materials being welded at LLNL.

The final tests involved laser-based detection. Since the materials as welded have smooth but not specularly reflecting surfaces, tests using a low laser power Michelson interferometer had a very low signal-to-noise ratio. Photorefractive interferometers, unlike Michelson interferometers, can work with somewhat diffusely reflecting surfaces and are more suitable for diffuse surfaces.

Figure 3 shows a signal-averaged waveform obtained using the photorefractive interferometer. A contact transducer was used to generate the waveform in Fig. 3. This particular test was not done through a window.

This project shows the potential for the application of laser-based ultrasound to Va and Ti alloys of interest to LLNL in laser welding stations.

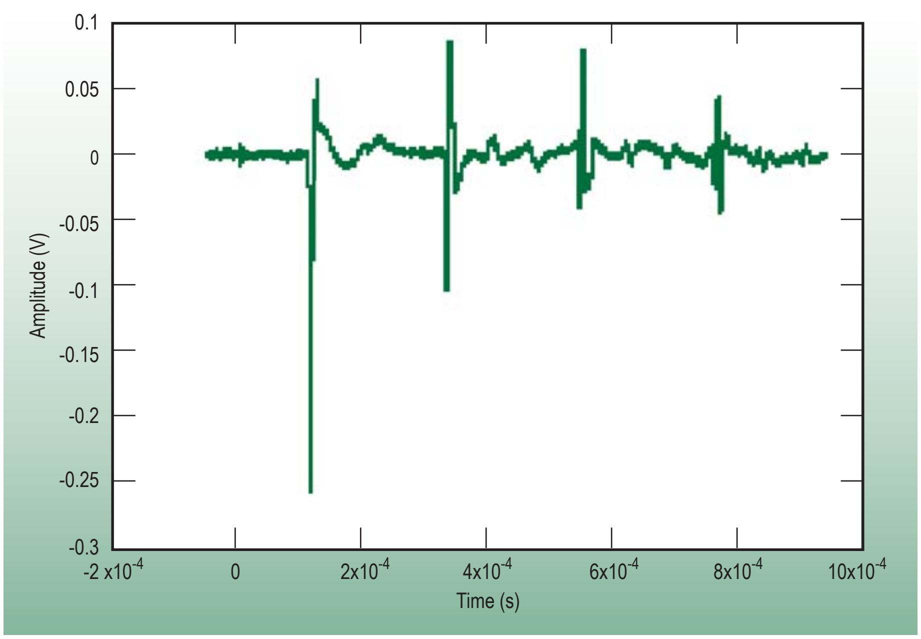

Figure 3. Contact transducer generated UT and detection of ultrasound using photorefractive interferometer.